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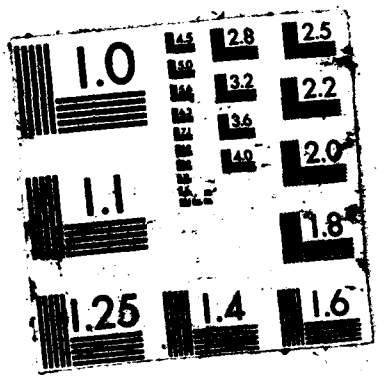
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The effect of a wavy wall boundary on the stability of a laminar boundary layer was studied analytically. It was found that Tollmien-Schlichting waves are not excited by the wavy boundary. Only standing waves are produced. A generalization of non-parallel stability formulations was developed for application to any two-dimensional free shear layer.

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Final Report

on

TIME-DEPENDENT HYPERSONIC VISCOUS INTERACTIONS

(AFOSR Grant No. AFOSR-81-0150)

for period ending 31 August 1984

Prepared by

Eli Reshotko
Principal Investigator

Department of Mechanical and Aerospace Engineering
Case Western Reserve University
Cleveland, Ohio 44106

June 1987

SUMMARY OF WORK

Under the subject grant, research was undertaken in three different topic areas. These are discussed successively:

1. Effects of Roughness on Stability and Transition of Low Speed Boundary Layers.

A study was initiated and completed (Ref. 1) of the initial value problem involving a wavy wall as one of the boundaries. The purpose of this study was to determine analytically the possible disturbances that could be introduced into a laminar boundary layer by a component of a wall roughness spectrum.

The solution shows that within the present framework of linear analysis, the wavy wall boundary does not excite the growing Tollmien-Schlichting wave. Rather it shows itself solely as producing standing waves as previously calculated by the same authors (Ref. 2). Accordingly the Tollmien-Schlichting waves are excited by other initial and boundary phenomena such as free-stream turbulence, acoustical disturbances, etc. We surmise that the influence of roughness on transition is through the local profile effects in the near vicinity of the distributed roughness. These local wakes of roughness elements can amplify the low frequency content of the tunnel turbulence in the manner described by the measurements of Leventhal and Reshotko (Refs. 3 and 4) and of Shin, Prahl and Reshotko (Ref. 5).

A paper summarizing all of the above findings was presented at the IUTAM Symposium on Turbulence and Chaotic Phenomena in Fluids held in Kyoto, Japan, 5-10 September 1983 (Ref. 6).

2. Non-Linear Stability Formulations

Most linear stability analyses are restricted to studies of the normal modes. However, the normal modes representation of a disturbance spectrum does not conveniently extend to finite amplitude, and so the nonlinear processes between initial instability and the completion of the transition process are to date not well understood.

The methods available in nonlinear stability analysis are of four types:

a) perturbation methods

b) asymptotic methods

c) variational methods

d) numerical solutions

During th last grant year, the above techniques were examined for their suitability in dealing with two kinds of problems: i) response of a flow to a spectrum of disturbances with the accompanying mode coupling, and ii) growth of disturbances in an environment that is initially nonlinear. Only the perturbation methods could in their limited way provide some analytic insight on the above problems. Numerical computation could at a later time provide more quantitative information.

Because of our experience with initial value problems (Ref. 1), we were attracted to the possibility of extending this technique into the nonlinear regime during the follow-on grant period.

3. Non-parallel Stability of Turbulent Free Shear Flows

While on a visit to Tel-Aviv University during the last three months of 1983, the principal investigator had the opportunity to participate in the work of Prof. Wygnanski's group, primarily in the area of turbulent free shear flows. In a paper by Gaster, Kit and Wygnanski (Ref. 7), it is shown that the large scale vortex structures that occur in a two-dimensional turbulent mixing layer can be modeled by non-parallel inviscid stability considerations. While in residence at Tel-Aviv University, the principal investigator reviewed for Wygnanski's group the analytical basis of non-parallel stability formulations and developed a generalization of that procedure that could be applied to any two-dimensional free shear layer (jet, wake, mixing layer).

As a result of the work done by the principal investigator under AFOSR and other grants, he has given numerous invited lectures on stability and transition of boundary layers and has had review articles published on this topic.

Through his chairmanship of the U.S. Boundary Layer Transition Study Group and his membership on an AGARD Working Group on Viscous Simulation, the principal investigator is continuing his studies of the influence of test facility on boundary layer transition. This is directed at establishing criteria for the acceptability of transition data from ground

test facilities and guidelines concerning their extrapolation to flight conditions. Further, it will help in establishing the basis for rational methods of transition prediction.

During the grant period, the principal investigator was appointed Chairman of the NASA Informal Advisory Subcommittee on Aerodynamics and also a member of the executive committee of NASA's Aeronautics Advisory Committee. He continues as a member of the Fluid Dynamics Panel of AGARD.

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